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(54) **VIRTUAL IMAGE DEVICE**

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H04N 9/31	(2006.01)
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CPC ***G02B 6/00*** (2013.01); *H04N 9/3108* (2013.01); *H04N 9/3197* (2013.01); ***G02B 27/22*** (2013.01); ***G02B 27/44*** (2013.01); ***G09G 5/00*** (2013.01); *G02B 2027/0174* (2013.01); *G02B 2027/0123* (2013.01); *G02B 2027/0178* (2013.01); *G02B 2027/0187* (2013.01)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,046,975	A	9/1977	Seeger, Jr.
4,065,649	A	12/1977	Carter et al.
4,239,338	A	12/1980	Borrelli et al.
4,243,861	A	1/1981	Strandwitz
4,302,648	A	11/1981	Sado et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1440513	9/2003
EP	0271956	6/1988

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion, Application No. PCT/US2013/051421, Dec. 6, 2013, 10 pages.

(Continued)

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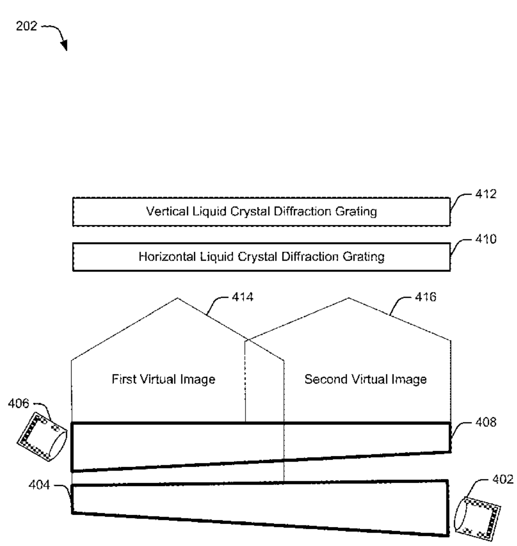
(57) **ABSTRACT**

This document describes various apparatuses embodying, and techniques for implementing, a virtual image device. The virtual image device includes a projector and a lens configured to generate a virtual image as well as two diffraction gratings, substantially orthogonally-oriented to each other, that act to increase a field-of-view of the virtual image. The virtual image device can be implemented as a pair of eyeglasses and controlled to generate the virtual image in front of lenses of the eyeglasses so that a wearer of the eyeglasses, looking through the lenses of the eyeglasses, sees the virtual image.

20 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,317,013	A	2/1982	Larson	
4,365,130	A	12/1982	Christensen	
4,492,829	A	1/1985	Rodrique	
4,527,021	A	7/1985	Morikawa et al.	
4,559,426	A	12/1985	Van Zeeland et al.	
4,576,436	A	3/1986	Daniel	
4,588,187	A	5/1986	Dell	
4,607,147	A	8/1986	Ono et al.	
4,615,579	A	10/1986	Whitehead	
4,651,133	A	3/1987	Ganesan et al.	
5,220,521	A	6/1993	Kikinis	
5,283,559	A	2/1994	Kalendra et al.	
5,331,443	A	7/1994	Stanisci	
5,339,382	A	8/1994	Whitehead	
5,406,415	A	4/1995	Kelly	
5,548,477	A	8/1996	Kumar et al.	
5,558,577	A	9/1996	Kato	
5,681,220	A	10/1997	Bertram et al.	
5,745,376	A	4/1998	Barker et al.	
5,748,114	A	5/1998	Koehn	
5,781,406	A	7/1998	Hunte	
5,807,175	A	9/1998	Davis et al.	
5,818,361	A	10/1998	Acevedo	
5,828,770	A	10/1998	Leis et al.	
5,861,990	A	1/1999	Tedesco	
5,874,697	A	2/1999	Selker et al.	
5,926,170	A	7/1999	Oba	
5,971,635	A	10/1999	Wise	
5,999,147	A	12/1999	Teitel	
6,002,389	A	12/1999	Kasser	
6,005,209	A	12/1999	Burleson et al.	
6,012,714	A	1/2000	Worley et al.	
6,040,823	A	3/2000	Seffernick et al.	
6,044,717	A	4/2000	Biegelsen et al.	
6,046,857	A	4/2000	Morishima	
6,061,644	A	5/2000	Leis	
6,178,443	B1	1/2001	Lin	
6,195,136	B1 *	2/2001	Handschy et al.	349/5
6,232,934	B1	5/2001	Heacock et al.	
6,254,105	B1	7/2001	Rinde et al.	
6,279,060	B1	8/2001	Luke et al.	
6,300,986	B1	10/2001	Travis	
6,329,617	B1	12/2001	Burgess	
6,344,791	B1	2/2002	Armstrong	
6,353,503	B1	3/2002	Spitzer et al.	
6,362,861	B1	3/2002	Hertz et al.	
6,380,497	B1	4/2002	Hashimoto et al.	
6,437,682	B1	8/2002	Vance	
6,469,755	B1	10/2002	Adachi et al.	
6,511,378	B1	1/2003	Bhatt et al.	
6,532,147	B1	3/2003	Christ, Jr.	
6,543,949	B1	4/2003	Ritchey et al.	
6,565,439	B2	5/2003	Shinohara et al.	
6,600,121	B1	7/2003	Olodort et al.	
6,603,408	B1	8/2003	Gaba	
6,617,536	B2	9/2003	Kawaguchi	
6,685,369	B2	2/2004	Lien	
6,704,864	B1	3/2004	Philyaw	
6,721,019	B2	4/2004	Kono et al.	
6,725,318	B1	4/2004	Sherman et al.	
6,774,888	B1	8/2004	Genduso	
6,776,546	B2	8/2004	Kraus et al.	
6,784,869	B1	8/2004	Clark et al.	
6,795,146	B2	9/2004	Dozov et al.	
6,813,143	B2	11/2004	Makela	
6,819,316	B2	11/2004	Schulz et al.	
6,833,955	B2 *	12/2004	Niv	359/566
6,847,488	B2	1/2005	Travis	
6,856,506	B2	2/2005	Doherty et al.	
6,861,961	B2	3/2005	Sandbach et al.	
6,914,197	B2	7/2005	Doherty et al.	
6,950,950	B2	9/2005	Sawyers et al.	
6,970,957	B1	11/2005	Oshins et al.	
6,976,799	B2	12/2005	Kim et al.	
7,007,238	B2	2/2006	Glaser	
7,025,908	B1	4/2006	Hayashi et al.	
7,051,149	B2	5/2006	Wang et al.	
7,058,252	B2 *	6/2006	Woodgate et al.	385/16
7,066,634	B2	6/2006	Kitamura et al.	
7,091,436	B2	8/2006	Serban	
7,101,048	B2	9/2006	Travis	
7,106,222	B2	9/2006	Ward et al.	
7,123,292	B1	10/2006	Seeger et al.	
7,152,985	B2	12/2006	Benitez et al.	
7,194,662	B2	3/2007	Do et al.	
7,199,931	B2	4/2007	Boettiger et al.	
7,213,991	B2	5/2007	Chapman et al.	
7,218,830	B2	5/2007	Iimura	
7,277,087	B2	10/2007	Hill et al.	
7,400,805	B2	7/2008	Abu-Ageel	
7,447,934	B2	11/2008	Dasari et al.	
7,469,386	B2	12/2008	Bear et al.	
7,499,037	B2	3/2009	Lube	
7,499,216	B2	3/2009	Niv et al.	
7,502,803	B2	3/2009	Culter et al.	
7,515,143	B2	4/2009	Keam et al.	
7,542,052	B2	6/2009	Solomon et al.	
7,558,594	B2	7/2009	Wilson	
7,559,834	B1	7/2009	York	
7,561,131	B2	7/2009	Ijzerman et al.	
7,636,921	B2	12/2009	Louie	
7,643,213	B2	1/2010	Boettiger et al.	
7,656,392	B2	2/2010	Bolender	
7,733,326	B1	6/2010	Adiseshan	
7,777,972	B1	8/2010	Chen et al.	
7,782,342	B2	8/2010	Koh	
7,813,715	B2	10/2010	McKillop et al.	
7,855,716	B2	12/2010	McCreary et al.	
7,884,807	B2	2/2011	Hovden et al.	
D636,397	S	4/2011	Green	
7,918,559	B2	4/2011	Tesar	
7,928,964	B2	4/2011	Kolmykov-Zotov et al.	
7,945,717	B2	5/2011	Rivalsi	
7,967,462	B2	6/2011	Ogiro et al.	
7,973,771	B2	7/2011	Geaghan	
7,978,281	B2	7/2011	Vergith et al.	
8,035,614	B2	10/2011	Bell et al.	
8,035,624	B2	10/2011	Bell et al.	
8,053,688	B2	11/2011	Conzola et al.	
8,065,624	B2	11/2011	Morin et al.	
8,069,356	B2	11/2011	Rathi et al.	
RE42,992	E	12/2011	David	
8,102,362	B2	1/2012	Ricks et al.	
8,115,718	B2	2/2012	Chen et al.	
8,130,203	B2	3/2012	Westerman	
8,154,524	B2	4/2012	Wilson et al.	
D659,139	S	5/2012	Gengler	
8,169,421	B2	5/2012	Wright et al.	
8,220,929	B2 *	7/2012	Miyawaki et al.	353/7
8,229,509	B2	7/2012	Paek et al.	
8,229,522	B2	7/2012	Kim et al.	
8,249,263	B2	8/2012	Cragun	
8,310,768	B2	11/2012	Lin et al.	
8,345,920	B2	1/2013	Ferren et al.	
8,416,206	B2	4/2013	Carpendale et al.	
8,466,902	B2	6/2013	Boer et al.	
8,582,206	B2	11/2013	Travis	
8,717,664	B2	5/2014	Wang et al.	
8,749,529	B2	6/2014	Powell et al.	
9,019,615		4/2015	Travis	
2002/0134828	A1	9/2002	Sandbach et al.	
2003/0165017	A1	9/2003	Amitai	
2003/0197687	A1	10/2003	Shetter	
2004/0052506	A1	3/2004	Togino	
2004/0174709	A1	9/2004	Buelow, II et al.	
2004/0258924	A1	12/2004	Berger et al.	
2004/0268000	A1	12/2004	Barker et al.	
2005/0001957	A1 *	1/2005	Amimori et al.	349/112
2005/0002073	A1	1/2005	Nakamura et al.	
2005/0057515	A1	3/2005	Bathiche	
2005/0059489	A1	3/2005	Kim	
2005/0100690	A1	5/2005	Mayer et al.	
2005/0146512	A1	7/2005	Hill et al.	
2005/0264653	A1	12/2005	Starkweather et al.	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0264988 A1 12/2005 Nicolosi
2006/0002101 A1 1/2006 Wheatley et al.
2006/0028400 A1 2/2006 Lapstun et al.
2006/0085658 A1 4/2006 Allen et al.
2006/0125799 A1 6/2006 Hillis et al.
2006/0154725 A1 7/2006 Glaser et al.
2006/0156415 A1 7/2006 Rubinstein et al.
2006/0181514 A1 8/2006 Newman
2006/0195522 A1 8/2006 Miyazaki
2006/0227393 A1 10/2006 Herloski
2006/0238550 A1 10/2006 Page
2006/0239006 A1 10/2006 Chaves et al.
2006/0279501 A1 12/2006 Lu et al.
2007/0002587 A1 1/2007 Miyashita
2007/0047260 A1 3/2007 Lee et al.
2007/0062089 A1 3/2007 Homer et al.
2007/0072474 A1 3/2007 Beasley et al.
2007/0182663 A1 8/2007 Biech
2007/0189667 A1 8/2007 Wakita et al.
2007/0234420 A1 10/2007 Novotney et al.
2007/0236408 A1 10/2007 Yamaguchi et al.
2007/0247432 A1 10/2007 Oakley
2007/0260892 A1 11/2007 Paul et al.
2007/0279744 A1 12/2007 Fujimoto
2007/0283179 A1 12/2007 Burnett et al.
2008/0005423 A1 1/2008 Jacobs et al.
2008/0080166 A1 4/2008 Duong et al.
2008/0088593 A1 4/2008 Smoot
2008/0094398 A1 4/2008 Ng et al.
2008/0104437 A1 5/2008 Lee
2008/0122803 A1 5/2008 Izadi et al.
2008/0150913 A1 6/2008 Bell et al.
2008/0151478 A1 6/2008 Chern
2008/0158185 A1 7/2008 Westerman
2008/0179507 A2 7/2008 Han
2008/0225205 A1 9/2008 Travis
2008/0238884 A1 10/2008 Harish
2008/0253822 A1 10/2008 Matias
2008/0316002 A1 12/2008 Brunet et al.
2008/0320190 A1 12/2008 Lydon et al.
2009/0009476 A1 1/2009 Daley, III
2009/0033623 A1 2/2009 Lin
2009/0067156 A1 3/2009 Bonnett et al.
2009/0073957 A1 3/2009 Newland et al.
2009/0096738 A1 4/2009 Chen et al.
2009/0140985 A1 6/2009 Liu
2009/0142020 A1 6/2009 Van Ostrand et al.
2009/0189974 A1 7/2009 Deering
2009/0200384 A1 8/2009 Masalkar
2009/0251008 A1 10/2009 Sugaya
2009/0262492 A1 10/2009 Whitchurch et al.
2009/0303204 A1 12/2009 Nasiri et al.
2009/0320244 A1 12/2009 Lin
2009/0321490 A1 12/2009 Groene et al.
2010/0001963 A1 1/2010 Doray et al.
2010/0026656 A1 2/2010 Hotelling et al.
2010/0038821 A1 2/2010 Jenkins et al.
2010/0045633 A1 2/2010 Gettemy
2010/0051432 A1 3/2010 Lin et al.
2010/0053534 A1 3/2010 Hsieh et al.
2010/0053771 A1 3/2010 Travis et al.
2010/0072351 A1 3/2010 Mahowald
2010/0077237 A1 3/2010 Sawyers
2010/0085321 A1 4/2010 Pundsack
2010/0102206 A1 4/2010 Cazaux et al.
2010/0103112 A1 4/2010 Yoo et al.
2010/0149073 A1 6/2010 Chaum et al.
2010/0149100 A1 6/2010 Meiby
2010/0149111 A1 6/2010 Olien
2010/0149117 A1 6/2010 Chien et al.
2010/0161522 A1 6/2010 Tirpak et al.
2010/0164857 A1 7/2010 Liu et al.
2010/0171891 A1 7/2010 Kaji et al.
2010/0174421 A1 7/2010 Tsai et al.
2010/0177388 A1 7/2010 Cohen et al.
2010/0180063 A1 7/2010 Ananny et al.
2010/0188299 A1 7/2010 Rinehart et al.
2010/0206614 A1 8/2010 Park et al.
2010/0214659 A1* 8/2010 Levola 359/566
2010/0222110 A1 9/2010 Kim et al.
2010/0250988 A1 9/2010 Okuda et al.
2010/0274932 A1 10/2010 Kose
2010/0279768 A1 11/2010 Huang et al.
2010/0282953 A1 11/2010 Tam
2010/0284085 A1* 11/2010 Laakkonen 359/575
2010/0289457 A1 11/2010 Onnerud et al.
2010/0295812 A1 11/2010 Burns et al.
2010/0296163 A1 11/2010 Saarikko
2010/0302378 A1 12/2010 Marks et al.
2010/0302469 A1* 12/2010 Yue et al. 349/18
2010/0306538 A1 12/2010 Thomas et al.
2010/0308778 A1 12/2010 Yamazaki et al.
2010/0308844 A1 12/2010 Day et al.
2010/0315348 A1 12/2010 Jellicoe et al.
2010/0325155 A1 12/2010 Skinner et al.
2011/0002577 A1 1/2011 Van Ostrand
2011/0007047 A1 1/2011 Fujioka et al.
2011/0012873 A1 1/2011 Prest et al.
2011/0019123 A1 1/2011 Prest et al.
2011/0031287 A1 2/2011 Le Gette et al.
2011/0032215 A1 2/2011 Sirotich et al.
2011/0035209 A1 2/2011 Macfarlane
2011/0037721 A1 2/2011 Cranfill et al.
2011/0043479 A1 2/2011 van Aerle et al.
2011/0043990 A1 2/2011 Mickey et al.
2011/0044579 A1 2/2011 Travis et al.
2011/0060926 A1 3/2011 Brooks et al.
2011/0069148 A1 3/2011 Jones et al.
2011/0072391 A1 3/2011 Hanggie et al.
2011/0074688 A1 3/2011 Hull et al.
2011/0096035 A1 4/2011 Shen
2011/0102326 A1 5/2011 Casparian et al.
2011/0122071 A1 5/2011 Powell
2011/0134032 A1 6/2011 Chiu et al.
2011/0163955 A1 7/2011 Nasiri et al.
2011/0164370 A1 7/2011 McClure et al.
2011/0167181 A1 7/2011 Minoo et al.
2011/0167287 A1 7/2011 Walsh et al.
2011/0167391 A1 7/2011 Momeyer et al.
2011/0169778 A1 7/2011 Nungester et al.
2011/0170289 A1 7/2011 Allen et al.
2011/0179864 A1 7/2011 Raasch et al.
2011/0184646 A1 7/2011 Wong et al.
2011/0193787 A1 8/2011 Morishige et al.
2011/0197156 A1 8/2011 Strait et al.
2011/0205372 A1 8/2011 Miramontes
2011/0216039 A1 9/2011 Chen et al.
2011/0227913 A1 9/2011 Hyndman
2011/0234535 A1 9/2011 Hung et al.
2011/0235179 A1 9/2011 Simmonds
2011/0242440 A1 10/2011 Noma et al.
2011/0242670 A1 10/2011 Simmonds
2011/0248920 A1 10/2011 Larsen
2011/0290686 A1 12/2011 Huang
2011/0291993 A1 12/2011 Miyazaki
2011/0297566 A1 12/2011 Gallagher et al.
2011/0304577 A1 12/2011 Brown
2011/0304815 A1 12/2011 Newell
2011/0316807 A1 12/2011 Corrion
2011/0317399 A1 12/2011 Hsu
2012/0007821 A1 1/2012 Zaliva
2012/0023459 A1 1/2012 Westerman
2012/0024682 A1 2/2012 Huang et al.
2012/0044179 A1 2/2012 Hudson
2012/0047368 A1 2/2012 Chinn et al.
2012/0050975 A1 3/2012 Garelli et al.
2012/0062850 A1 3/2012 Travis
2012/0068919 A1 3/2012 Lauder et al.
2012/0075249 A1 3/2012 Hoch
2012/0092279 A1 4/2012 Martin
2012/0094257 A1 4/2012 Pillischer et al.
2012/0099749 A1 4/2012 Rubin et al.
2012/0102436 A1 4/2012 Nurmi
2012/0102438 A1 4/2012 Robinson et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0113031	A1	5/2012	Lee et al.
2012/0113223	A1	5/2012	Hilliges et al.
2012/0117409	A1	5/2012	Lee et al.
2012/0127118	A1	5/2012	Nolting et al.
2012/0140396	A1	6/2012	Zeliff et al.
2012/0145525	A1	6/2012	Ishikawa
2012/0146943	A1	6/2012	Fairley et al.
2012/0162088	A1	6/2012	van Lieshout et al.
2012/0162126	A1	6/2012	Yuan et al.
2012/0162693	A1	6/2012	Ito
2012/0170284	A1	7/2012	Shedletsky
2012/0182242	A1	7/2012	Lindahl et al.
2012/0182743	A1	7/2012	Chou
2012/0188243	A1	7/2012	Fujii et al.
2012/0194448	A1	8/2012	Rothkopf
2012/0195063	A1	8/2012	Kim et al.
2012/0200532	A1	8/2012	Powell et al.
2012/0224073	A1	9/2012	Miyahara
2012/0243102	A1	9/2012	Takeda et al.
2012/0243204	A1	9/2012	Robinson
2012/0246377	A1	9/2012	Bhesania
2012/0256959	A1	10/2012	Ye et al.
2012/0268912	A1	10/2012	Minami et al.
2012/0274811	A1	11/2012	Bakin
2012/0300275	A1	11/2012	Vilardell et al.
2013/0027354	A1	1/2013	Yabuta et al.
2013/0063873	A1	3/2013	Wodrich et al.
2013/0106813	A1	5/2013	Hotelling et al.
2013/0107572	A1	5/2013	Holman et al.
2013/0120760	A1	5/2013	Raguin et al.
2013/0181926	A1	7/2013	Lim
2013/0207896	A1	8/2013	Robinson et al.
2013/0222353	A1	8/2013	Large
2013/0229357	A1	9/2013	Powell
2013/0265220	A1	10/2013	Fleischmann et al.
2013/0329301	A1	12/2013	Travis
2013/0332628	A1	12/2013	Panay
2014/0022629	A1	1/2014	Powell
2014/0098085	A1	4/2014	Lee
2014/0168131	A1	6/2014	Rihn
2014/0233237	A1	8/2014	Lutian
2014/0254032	A1	9/2014	Chen

FOREIGN PATENT DOCUMENTS

EP	2353978	8/2011
EP	2381290	10/2011
JP	10301055	11/1998
JP	10326124	12/1998
JP	2001174746	6/2001
JP	2009003053	1/2009
JP	2009122551	6/2009
KR	20110064265	6/2011
WO	WO-9964784	12/1999
WO	WO-0079327	12/2000
WO	WO-2011016200	2/2011
WO	WO-2012063410	5/2012

OTHER PUBLICATIONS

International Search Report and Written Opinion, Application No. PCT/US2013/063156, Dec. 5, 2013, 9 pages.
Non-Final Office Action, U.S. Appl. No. 13/409,967, Dec. 10, 2013, 5 pages.
Non-Final Office Action, U.S. Appl. No. 13/408,257, Dec. 5, 2013, 13 pages.
Notice of Allowance, U.S. Appl. No. 13/409,967, Feb. 14, 2014, 4 pages.
Restriction Requirement, U.S. Appl. No. 13/494,722, Dec. 20, 2013, 6 pages.
"Accessing Device Sensors", retrieved from <https://developer.palm.com/content/api/dev-guide/pdk/accessing-device-sensors.html> on May 25, 2012, 4 pages.
"ACPI Docking for Windows Operating Systems", Retrieved from: <http://www.scritube.com/limba/engleza/software/ACPI-Docking-for-Windows-Opera331824193.php> on Jul. 6, 2012,10 pages.
"Cirago Slim Case®—Protective case with built-in kickstand for your iPhone 5®", Retrieved from <http://cirago.com/wordpress/wp-content/uploads/2012/10/ipc1500brochure1.pdf> on Jan. 29, 2013, 1 page.
"First One Handed Fabric Keyboard with Bluetooth Wireless Technology", Retrieved from: <http://press.xtvworld.com/article3817.html> on May 8, 2012,(Jan. 6, 2005), 2 pages.
"Force and Position Sensing Resistors: An Emerging Technology", *Interlink Electronics*, Available at <http://staff.science.uva.nl/~vlaander/docu/FSR/An_Exploring_Technology.pdf>,(Feb. 1990), pp. 1-6.
"Frogpad Introduces Weareable Fabric Keyboard with Bluetooth Technology", Retrieved from: <http://www.geekzone.co.nz/content.asp?contentid=3898> on May 7, 2012,(Jan. 7, 2005), 3 pages.
"Incipio LG G-Slate Premium Kickstand Case—Black Nylon", Retrieved from: <http://www.amazon.com/Incipio-G-Slate-Premium-Kickstand-Case/dp/B004ZKP916> on May 8, 2012, 4 pages.
International Search Report and Written Opinion, International Application No. PCT/US2011/050471, (Apr. 9, 2012), 8 pages.
"Membrane Keyboards & Membrane Keypads", Retrieved from: <http://www.pannam.com/> on May 9, 2012,(Mar. 4, 2009), 2 pages.
"Microsoft Reveals Futuristic 3D Virtual HoloDesk Patent", Retrieved from <http://www.patentbolt.com/2012/05/microsoft-reveals-futuristic-3d-virtual-holodesk-patent.htmlt> on May 28, 2012, (May 23, 2012), 9 pages.
"Motion Sensors", *Android Developers*, retrieved from <http://developer.android.com/guide/topics/sensors/sensors_motion.html> on May 25, 2012, 7 pages.
Non-Final Office Action, U.S. Appl. No. 12/882,994, (Feb. 1, 2013),17 pages.
Non-Final Office Action, U.S. Appl. No. 13/471,001, (Feb. 19, 2013),15 pages.
Non-Final Office Action, U.S. Appl. No. 13/471,139, (Mar. 21, 2013),12 pages.
Non-Final Office Action, U.S. Appl. No. 13/471,202, (Feb. 11, 2013),10 pages.
Non-Final Office Action, U.S. Appl. No. 13/471,336, (Jan. 18, 2013),14 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,195, (Jan. 2, 2013),14 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,232, (Jan. 17, 2013),15 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,272, (Feb. 12, 2013),10 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,287, (Jan. 29, 2013),13 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,304, (Mar. 22, 2013), 9 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,327, (Mar. 22, 2013), 6 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,871, (Mar. 18, 2013),14 pages.
Non-Final Office Action, U.S. Appl. No. 13/651,976, (Feb. 22, 2013),16 pages.
Non-Final Office Action, U.S. Appl. No. 13/653,321, (Feb. 1, 2013),13 pages.
Non-Final Office Action, U.S. Appl. No. 13/653,682, (Feb. 7, 2013),11 pages.
Notice of Allowance, U.S. Appl. No. 13/470,633, (Mar. 22, 2013), 7 pages.
"Position Sensors", Android Developers, retrieved from <http://developer.android.com/guide/topics/sensors/sensors_position.html> on May 25, 2012, 5 pages.
Restriction Requirement, U.S. Appl. No. 13/471,139, (Jan. 17, 2013), 7 pages.
Restriction Requirement, U.S. Appl. No. 13/651,304, (Jan. 18, 2013), 7 pages.
Restriction Requirement, U.S. Appl. No. 13/651,726, (Feb. 22, 2013), 6 pages.

(56) **References Cited**

OTHER PUBLICATIONS

Restriction Requirement, U.S. Appl. No. 13/651,871, (Feb. 7, 2013), 6 pages.
"SoIRxTM E-Series Multidirectional Phototherapy ExpandableTM 2-Bulb Full Body Panel System", Retrieved from: < http://www.solarcsystems.com/us_multidirectional_uv_light_therapy_1_intro.html > on Jul. 25, 2012,(2011), 4 pages.
"The Microsoft Surface Tablets Comes With Impressive Design and Specs", Retrieved from <http://microsofttabletreview.com/the-microsoft-surface-tablets-comes-with-impressive-design-and-specs> on Jan. 30, 2013, (Jun. 2012), 2 pages.
"Tilt Shift Lenses: Perspective Control", retrieved from http://www.cambridgeincolour.com/tutorials/tilt-shift-lenses1.htm, (Mar. 28, 2008),11 Pages.
"Virtualization Getting Started Guide", *Red Hat Enterprise Linux 6, Edition 0.2*, retrieved from <http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/6/html-single/Virtualization_Getting_Started_Guide/index.html> on Jun. 13, 2012, 24 pages.
"What is Active Alignment?", http://www.kasalis.com/active_alignment.html, retrieved on Nov. 22, 2012, 2 Pages.
Bert, et al., "Passive Matrix Addressing of Electrophoretic Image Display", *Conference on International Display Research Conference*, Retrieved from <http://www.cmst.be/publi/eurodisplay2002_s14-1.pdf>, (Oct. 1, 2002), 4 pages.
Block, Steve et al., "DeviceOrientation Event Specification", *W3C, Editor's Draft*, retrieved from <https://developer.palm.com/content/api/dev-guide/pdk/accessing-device-sensors.html> on May 25, 2012,(Jul. 12, 2011),14 pages.
Brown, Rich "Microsoft Shows Off Pressure-Sensitive Keyboard", retrieved from <http://news.cnet.com/8301-17938_105-10304792-1.html> on May 7, 2012, (Aug. 6, 2009), 2 pages.
Burge, et al., "Determination of off-axis aberrations of imaging systems using on-axis measurements", *SPIE Proceeding*, Retrieved from <http://www.loft.opics.arizona.edu/documents/journal_articles/Jim_Burge_Determination_of_off-axis_aberrations_of_imaging_systems_using_on-axis_measurements.pdf>,(Sep. 21, 2011),10 pages.
Butler, Alex et al., "SideSight: Multi-"touch" Interaction around Small Devices", *In the proceedings of the 21st annual ACM symposium on User interface software and technology.*, retrieved from <http://research.microsoft.com/pubs/132534/sidesight_crv3.pdf> on May 29, 2012,(Oct. 19, 2008), 4 pages.
Chang, Jee-Gong et al., "Optical Design and Analysis of LCD Backlight Units Using ASAP", *Optical Engineering*, Available at <http://www.opticsvalley.com/resources/kbasePDF/ma_oe_001_optical_design.pdf>,(Jun. 2003),15 pages.
Crider, Michael "Sony Slate Concept Tablet "Grows" a Kickstand", Retrieved from: <http://androidcommunity.com/sony-slate-concept-tablet-grows-a-kickstand-20120116/> on May 4, 2012,(Jan. 16, 2012), 9 pages.
Dietz, Paul H., et al., "A Practical Pressure Sensitive Computer Keyboard", In Proceedings of UIST 2009,(Oct. 2009), 4 pages.
Diverdi, et al., "An Immaterial Pseudo-3D Display with 3D Interaction", *In the proceedings of Three-Dimensional Television: Capture, Transmission, and Display, Springer*, Retrieved from <http://www.cs.ucsb.edu/~holl/pubs/DiVerdi-2007-3DTV.pdf>,(Feb. 6, 2007), 26 pages.
Glatt, Jeff "Channel and Key Pressure (Aftertouch).", Retrieved from: <http://home.roadrunner.com/~jgglatt/tutr/touch.htm> on Jun. 11, 2012, 2 pages.
Grossman, et al., "Multi-Finger Gestural Interaction with 3D Volumetric Displays", *In the proceedings of the 17th annual ACM symposium on User interface software and technology*, Retrieved from <http://www.dgp.toronto.edu/papers/tgrossman_UIST2004.pdf>,(Oct. 24, 2004), pp. 61-70.
Hanlon, Mike "ElekTex Smart Fabric Keyboard Goes Wireless", Retrieved from: <http://www.gizmag.com/go/5048/ > on May 7, 2012,(Jan. 15, 2006), 5 pages.
Izadi, Shahram et al., "ThinSight: A Thin Form-Factor Interactive Surface Technology", *Communications of the ACM*, vol. 52, No. 12, retrieved from <http://research.microsoft.com/pubs/132532/p90-izadi.pdf> on Jan. 5, 2012,(Dec. 2009), pp. 90-98.
Kaur, Sukhmani "Vincent Liew's redesigned laptop satisfies ergonomic needs", Retrieved from: <http://www.designbuzz.com/entry/vincent-liew-s-redesigned-laptop-satisfies-ergonomic-needs/> on Jul. 27, 2012,(Jun. 21, 2010), 4 pages.
Khuntontong, Puttachat et al., "Fabrication of Molded Interconnection Devices by Ultrasonic Hot Embossing on Thin Polymer Films", IEEE Transactions on Electronics Packaging Manufacturing, vol. 32, No. 3,(Jul. 2009), pp. 152-156.
Lee, C.M.G "Flat-Panel Autostereoscopic 3D Display", *Optoelectronics, IET*, Available at <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04455550>,(Feb. 2008),pp. 24-28.
Lee, et al., "Depth-Fused 3D Imagery on an Immaterial Display", *In the proceedings of IEEE Transactions on Visualization and Computer Graphics*, vol. 15, No. 1, Retrieved from <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04540094>,(Jan. 2009), 20-33.
Lee, et al., "LED Light Coupler Design for a Ultra Thin Light Guide", *Journal of the Optical Society of Korea*, vol. 11, Issue.3, Retrieved from <http://opticslab.kongju.ac.kr/pdf/06.pdf>,(Sep. 2007), 5 pages.
Linderholm, Owen "Logitech Shows Cloth Keyboard for PDAs", Retrieved from: <http://www.pcworld.com/article/89084/logitech_shows_cloth_keyboard_for_pdas.html> on May 7, 2012,(Mar. 15, 2002), 5 pages.
Liu, et al., "Three-dimensional PC: toward novel forms of human-computer interaction", *In the proceedings of Three-Dimensional Video and Display: Devices and Systems* vol. CR76, Retrieved from <http://www.google.co.in/url?sa=t&rct=j&q=Three-dimensional+PC:+toward+novel+forms+of+human-computer+interaction&source=web&cd=1&ved=0CFoQFjAA&url=http%3A%2F%2Fciteseerx.ist.psu.ed%2Fviewdoc%2Fdownload%3Fdoi%3D10.1.1.32.9469%26rep%3Drep1%26,(Nov. 5, 2000), pp. 250-281.
McLellan, Charles "Eleksen Wireless Fabric Keyboard: a first look", Retrieved from: <http://www.zdnetasia.com/eleksen-wireless-fabric-keyboard-a-first-look-40278954.htm> on May 5, 2012,(Jul. 17, 2006), 9 pages.
Peli, Eli "Visual and Optometric Issues with Head-Mounted Displays", *IS & T/OSA Optics & Imaging in the Information Age, The Society for Imaging Science and Technology*, available at <http://www.u.arizona.edu/~zrui3/zhang_pHMPD_spie07.pdf>,(1996), pp. 364-369.
Post, E.R. et al., "E-Broidery: Design and Fabrication of Textile-Based Computing", IBM Systems Journal, vol. 39, Issue 3 & 4,(Jul. 2000), pp. 840-860.
Purcher, Jack "Apple is Paving the Way for a New 3D GUI for IOS Devices", Retrieved from: <http://www.patentlyapple.com/patently-apple/2012/01/apple-is-paving-the-way-for-a-new-3d-gui-for-ios-devices.html> on Jun. 4, 2012,(Jan. 12, 2012), 15 pages.
Reisman, et al., "A Screen-Space Formulation for 2D and 3D Direct Manipulation", *In the proceedings of the 22nd annual ACM symposium on User interface*, Retrieved from <http://innovis.cpsc.ucalgary.ca/innovis/uploads/Courses/TableTopDetails2009/Reisman2009.pdf>,(Oct. 4, 2009), pp. 69-78.
Schoning, Johannes et al., "Building Interactive Multi-Touch Surfaces", *Journal of Graphics, GPU, and Game Tools*, vol. 14, No. 3, available at <http://www.libavg.com/raw-attachment/wiki/Multitouch/Multitouchguide_draft.pdf>,(Nov. 2009), pp. 35-55.
Takamatsu, Seiichi et al., "Flexible Fabric Keyboard with Conductive Polymer-Coated Fibers", In Proceedings of Sensors 2011,(Oct. 28, 2011), 4 pages.
Yan, Jin-Ren et al., "Edge-Lighting Light Guide Plate Based on Micro-Prism for Liquid Crystal Display", *Journal of Display Technology*, vol. 5, No. 9, Available at <http://ieeexplore.ieee.org/ielx5/9425/5196834/05196835.pdf?tp=&arnumber=5196835&isnumber=5196834>,(Sep. 2009), pp. 355-357.
Yu, et al., "A New Driving Scheme for Reflective Bistable Cholesteric Liquid Crystal Displays", *Society for Information Display International Symposium Digest of Technical Papers*, Retrieved from <http://www.ee.ust.hk/~eekwok/publications/1997/bcd_sid.pdf>,(May 1997), 4 pages.

(56) **References Cited**

OTHER PUBLICATIONS

Zhang, et al., “Model-Based Development of Dynamically Adaptive Software”, *In Proceedings of ICSE 2006*, Available at <http://www.irisa.fr/lande/lande/icse-proceedings/icse/p371.pdf>,(May 20, 2006), pp. 371-380.
Zhang, Rui “Design of Head Mounted Displays”, Retrieved at <<http://www.optics.arizona.edu/optomech/student%20reports/2007/Design%20of%20mounteddisplays%20Zhang.pdf>>, (Dec. 12, 2007), 6 pages.
Final Office Action, U.S. Appl. No. 13/408,257, Mar. 28, 2014, 17 pages.
Foreign Office Action, CN Application No. 201320328022.1, Oct. 18, 2013, 3 Pages.
Foreign Office Action, CN Application No. 201320328022.1, Feb. 17, 2014, 4 Pages.
Non-Final Office Action, U.S. Appl. No. 13/494,722, May 9, 2014, 8 pages.
Non-Final Office Action, U.S. Appl. No. 13/492,232, Apr. 30, 2014, 9 pages.
International Search Report and Written Opinion, Application No. PCT/US2014/020050, May 9, 2014, 10 pages.
International Search Report and Written Opinion, Application No. PCT/US2014/016654, May 16, 2014, 11 pages.
International Search Report and Written Opinion, Application No. PCT/US2013/075180, May 6, 2014, 12 pages.
Non-Final Office Action, U.S. Appl. No. 13/408,257, Jul. 2, 2014, 20 pages.
Non-Final Office Action, U.S. Appl. No. 13/647,507, Jun. 19, 2014, 22 pages.
Non-Final Office Action, U.S. Appl. No. 13/714,401, Jul. 8, 2014, 11 pages.
Non-Final Office Action, U.S. Appl. No. 13/773,496, Jun. 23, 2014, 10 pages.
PCT Search Report and Written Opinion, Application No. PCT/US2013/028479, (Jun. 17, 2013),10 pages.
PCT Search Report, Application No. PCT/US2013/042790, (Aug. 8, 2013), 9 pages.
Notice of Allowance, U.S. Appl. No. 12/882,994, (Jul. 12, 2013), 9 pages.
Chinese Search Report, Application No. 201110272868.3, (Apr. 1, 2013),10 pages.
International Search Report and Written Opinion, Application No. PCT/US2013/042550, (Sep. 24, 2013),14 pages.
“Welcome to Windows 7”, Retrieved from: <http://www.microsoft.com/en-us/download/confirmation.aspx?id=4984> on Aug. 1, 2013, (Sep. 16, 2009), 3 pages.
Prospero, Michael “Samsung Outs Series 5 Hybrid PC Tablet”, Retrieved from: <http://blog.laptopmag.com/samsung-outs-series-5-hybrid-pc-tablet-running-windows-8> on Oct. 31, 2013, (Jun. 4, 2012), 7 pages.
“For any kind of proceeding 2011 springtime as well as coil nailers as well as hotter summer season”, Retrieved at <<http://www.ladyshoesworld.com/2011/09/18/for-any-kind-of-proceeding-2011-springtime-as-well-as-coil-nailers-as-well-as-hotter-summer-season/>> Sep. 18, 2011, pp. 2.
Travis, et al., “Flat Projection for 3-D”, Retrieved at <<http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=01605201>> In the Proceedings of the IEEE, vol. 94, No. 3, Mar. 3, 2006, pp. 539-549.
“Microsoft Develops Glasses-Free Eye-Tracking 3D Display”, Retrieved at <<http://www.tech-faq.com/microsoft-develops-glasses-free-eye-tracking-3d-display.html>> Retrieved Date: Nov. 2, 2011, pp. 3.
Final Office Action, U.S. Appl. No. 13/492,232, Nov. 17, 2014, 13 pages.
Final Office Action, U.S. Appl. No. 13/647,507, Oct. 27, 2014, 33 pages.
Final Office Action, U.S. Appl. No. 13/714,401, Nov. 25, 2014, 15 pages.
Final Office Action, U.S. Appl. No. 13/773,496, Nov. 4, 2014, 11 pages.
Non-Final Office Action, U.S. Appl. No. 13/786,233, Nov. 20, 2014, 13 pages.
Written Opinion, Application No. PCT/US2014/020050, Sep. 22, 2014, 6 Pages.
“Final Office Action”, U.S. Appl. No. 13/408,257, Dec. 10, 2014, 15 pages.
“Non-Final Office Action”, U.S. Appl. No. 13/492,232, Feb. 24, 2015, 12 pages.
“Non-Final Office Action”, U.S. Appl. No. 13/647,507, Feb. 9, 2015, 37 pages.
“Notice of Allowance”, U.S. Appl. No. 13/494,722, Dec. 18, 2014, 7 pages.
“Advisory Action”, U.S. Appl. No. 13/408,257, Apr. 8, 2015, 9 pages.
“Non-Final Office Action”, U.S. Appl. No. 13/714,401, Apr. 17, 2015, 14 pages.

* cited by examiner

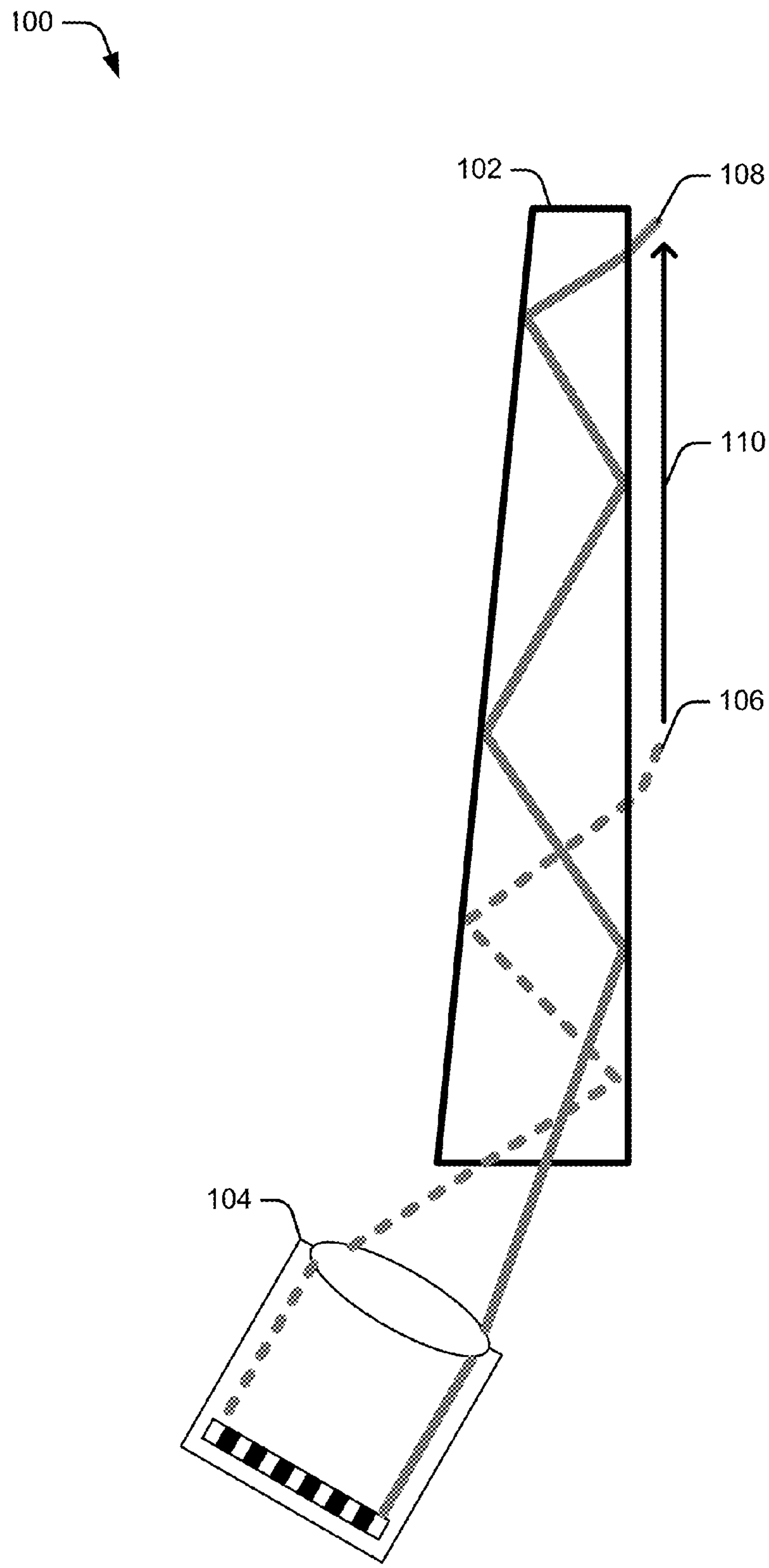


Fig. 1

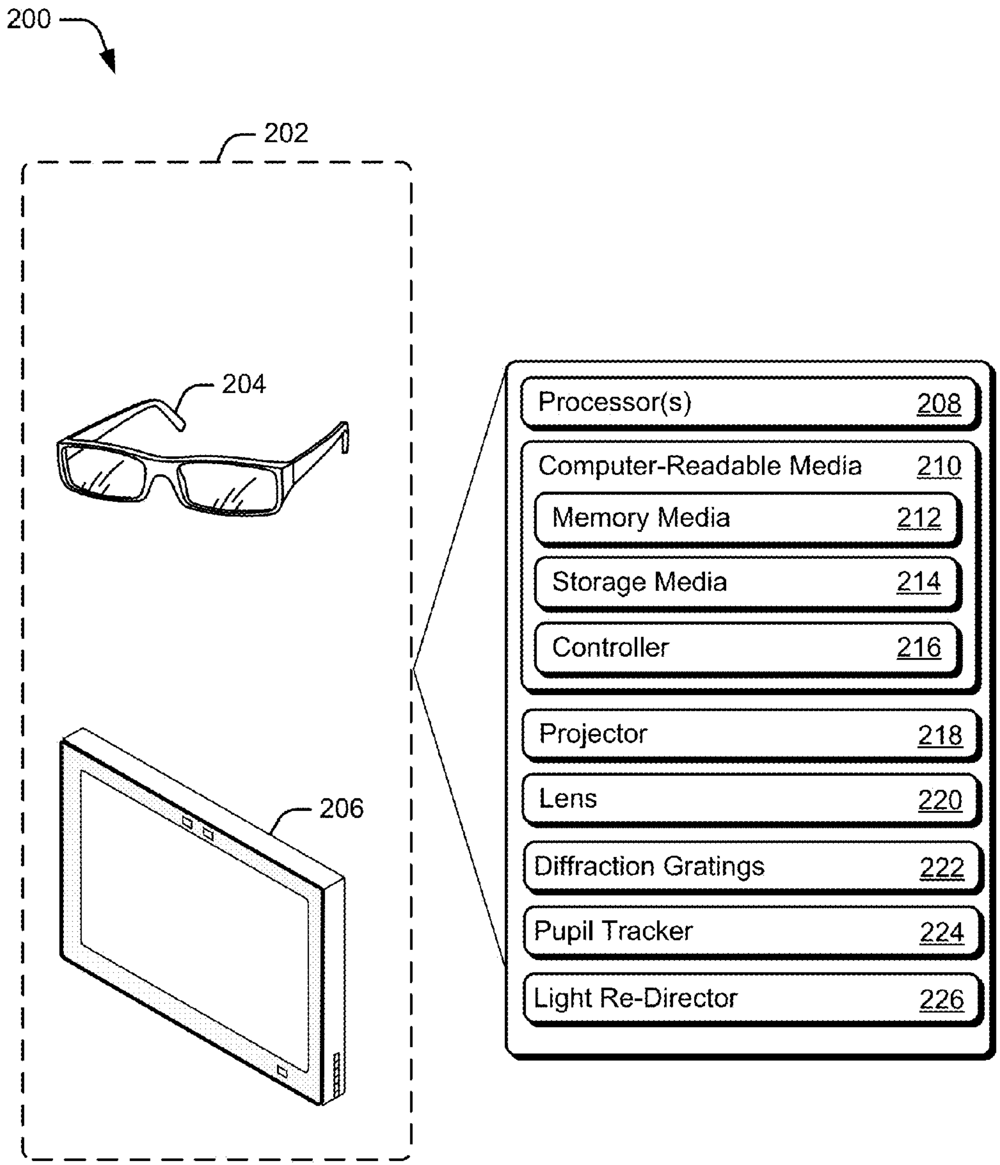

200
202
204
206
Processor(s) 208
Computer-Readable Media 210
Memory Media 212
Storage Media 214
Controller 216
Projector 218
Lens 220
Diffraction Gratings 222
Pupil Tracker 224
Light Re-Director 226

Fig. 2

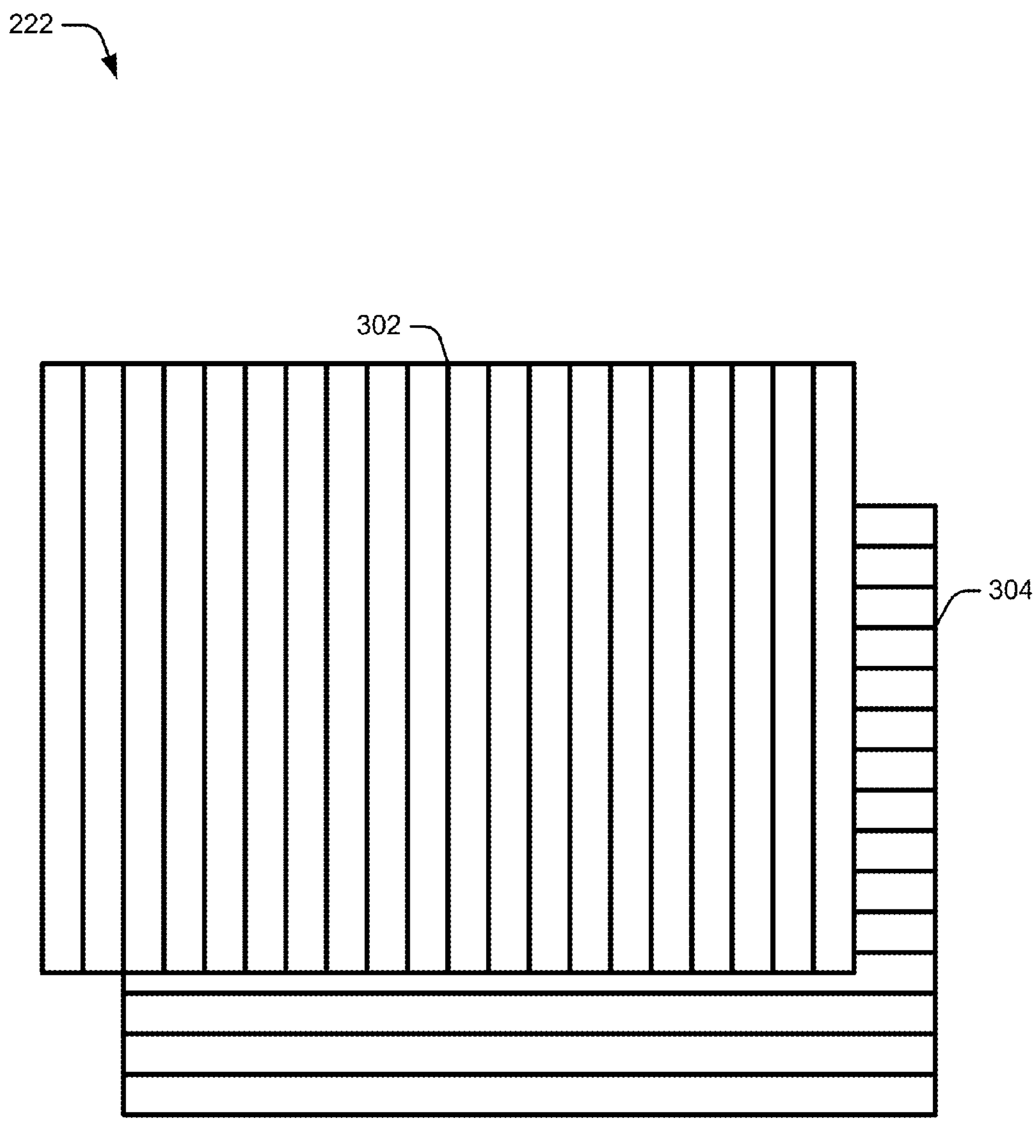


Fig. 3

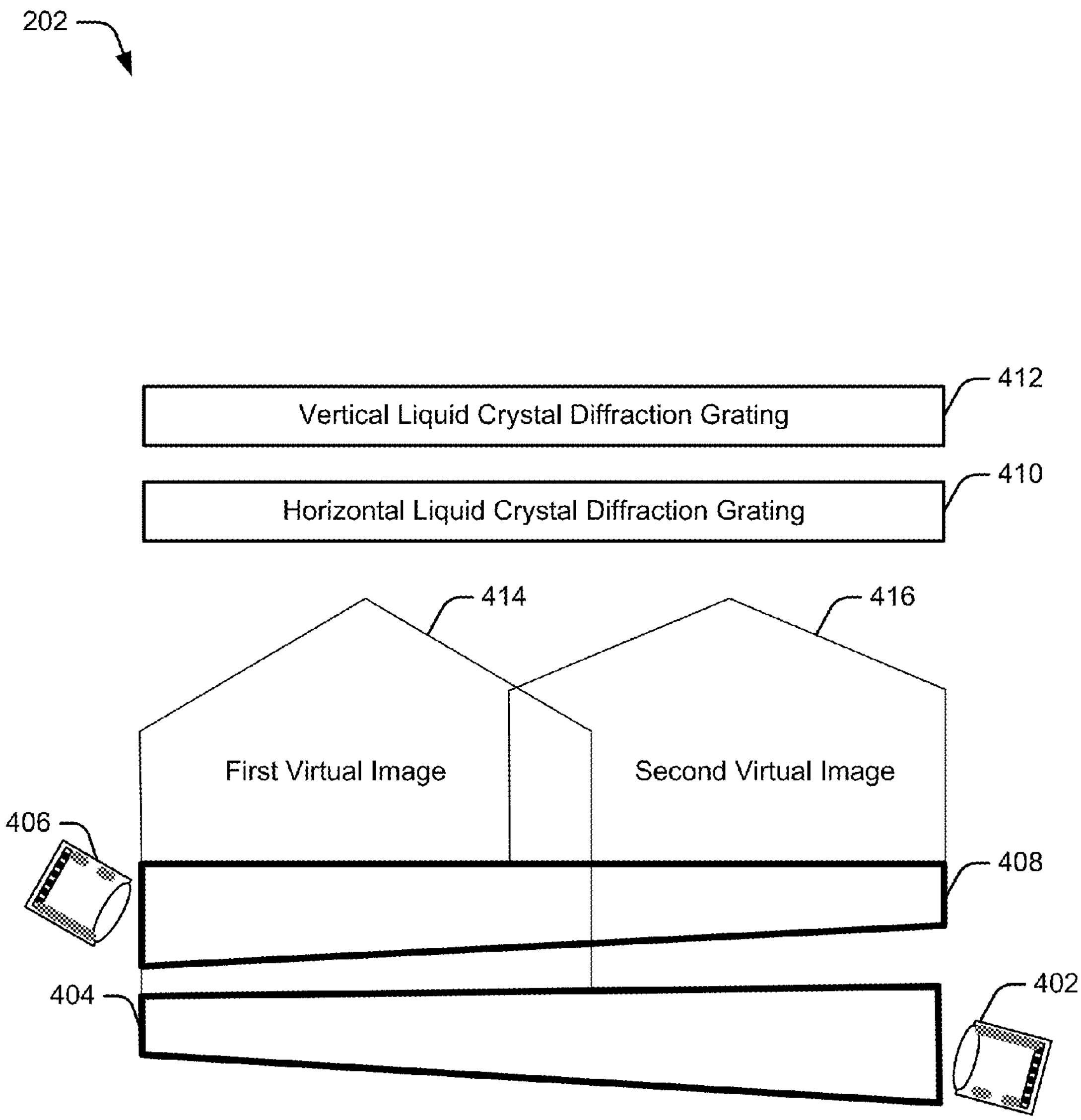

202
412
Vertical Liquid Crystal Diffraction Grating
410
Horizontal Liquid Crystal Diffraction Grating
414
416
First Virtual Image
Second Virtual Image
406
408
404
402

Fig. 4

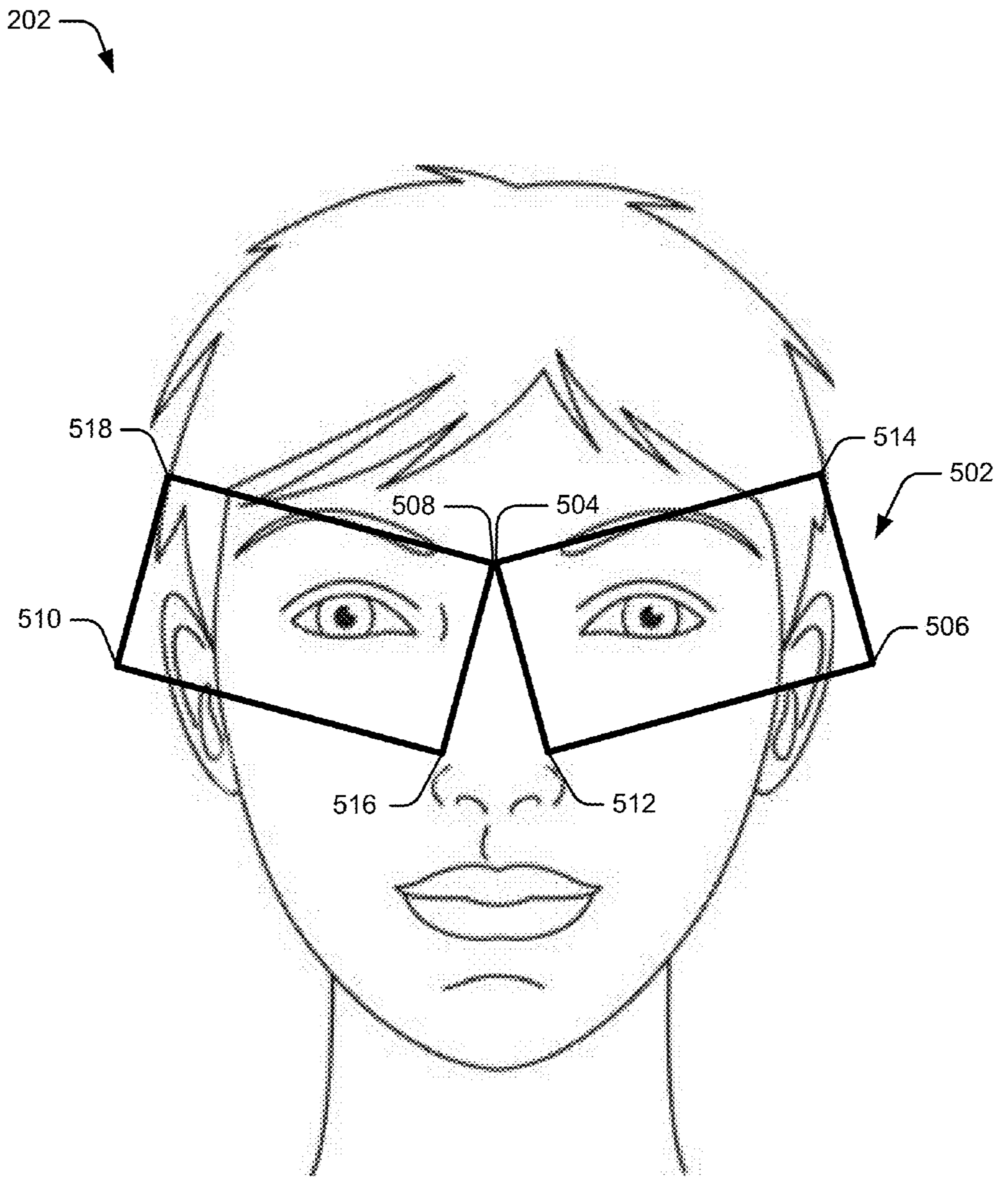


Fig. 5

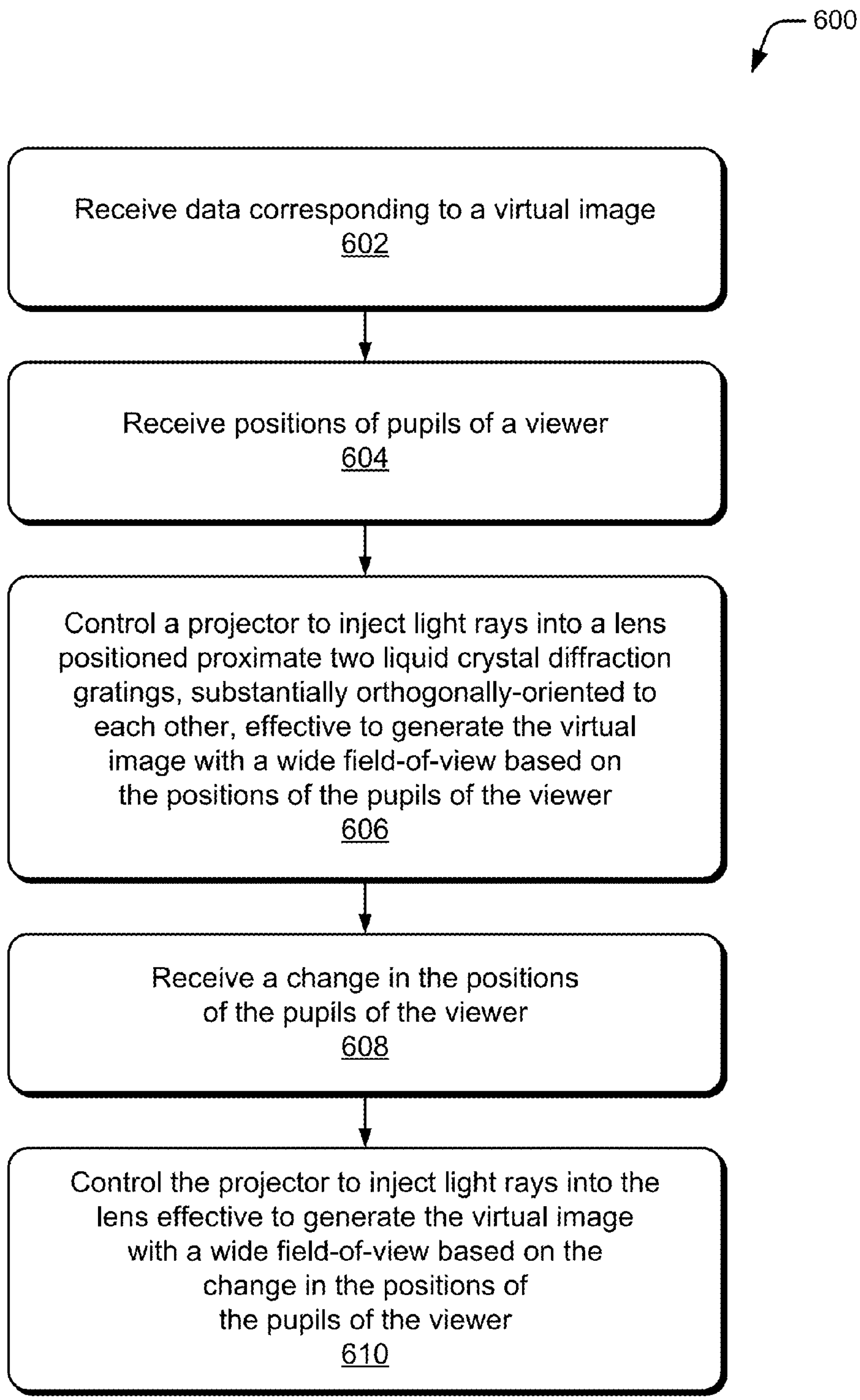

600
Receive data corresponding to a virtual image
602
Receive positions of pupils of a viewer
604
Control a projector to inject light rays into a lens positioned proximate two liquid crystal diffraction gratings, substantially orthogonally-oriented to each other, effective to generate the virtual image with a wide field-of-view based on the positions of the pupils of the viewer
606
Receive a change in the positions of the pupils of the viewer
608
Control the projector to inject light rays into the lens effective to generate the virtual image with a wide field-of-view based on the change in the positions of the pupils of the viewer
610

Fig. 6

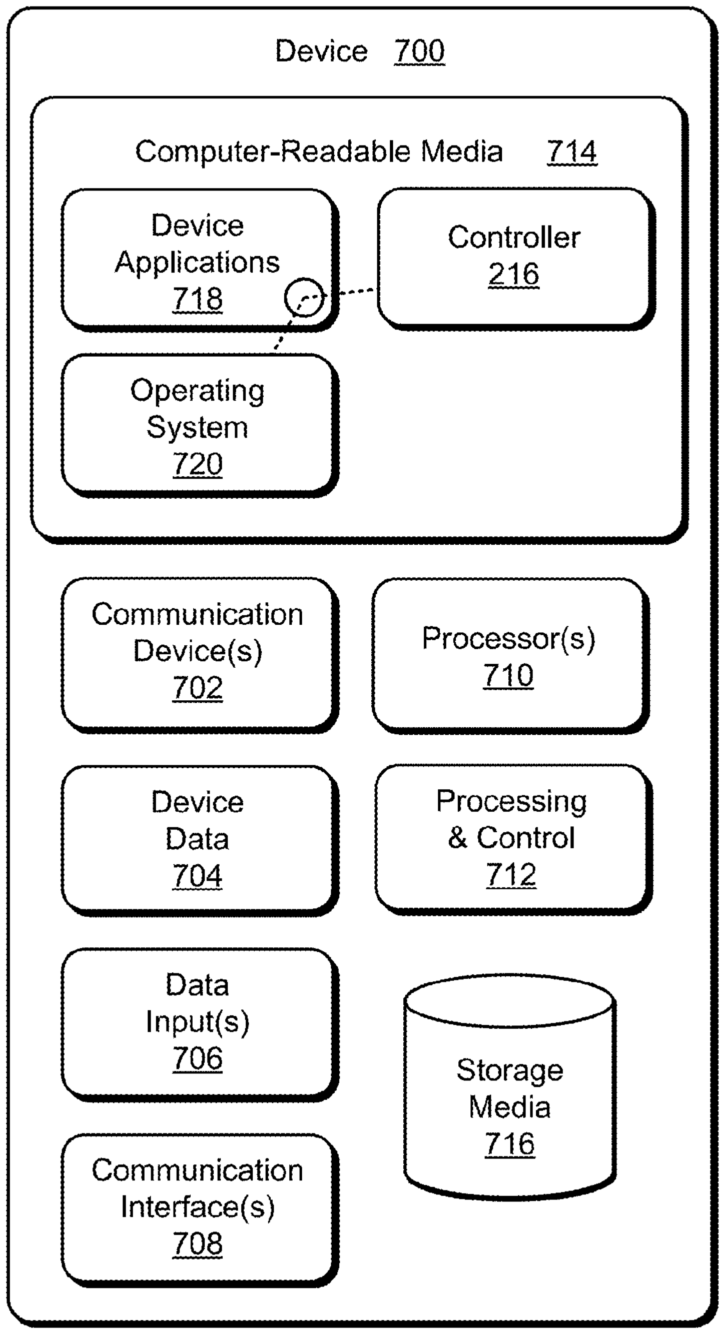

Device 700
Computer-Readable Media 714
Device Applications 718
Controller 216
Operating System 720
Communication Device(s) 702
Processor(s) 710
Device Data 704
Processing & Control 712
Data Input(s) 706
Storage Media 716
Communication Interface(s) 708

Fig. 7

VIRTUAL IMAGE DEVICE

BACKGROUND

A virtual image can be made by pointing a video projector into a lens to project the virtual image from a surface of the lens. A pair of eyeglasses, or spectacles, can include a virtual image projector to project a virtual image in front of the eyes of a wearer of the eyeglasses. Virtual image projectors small enough to be placed on a pair of eyeglasses, however, typically project a virtual image with a narrow field-of-view.

SUMMARY

This document describes various apparatuses embodying, and techniques for implementing, a virtual image device. The virtual image device includes a projector and a lens configured to generate a virtual image as well as two diffraction gratings, substantially orthogonally-oriented to each other, that act to increase a field-of-view of the virtual image. The virtual image device can be implemented as a pair of eyeglasses and controlled to generate the virtual image in front of lenses of the eyeglasses so that a wearer of the eyeglasses sees the virtual image. This summary is provided to introduce simplified concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of a virtual image device are described with reference to the following drawings. The same numbers are used throughout the drawings to reference like features and components:

FIG. **1** illustrates an example environment of a projector and a wedge light guide configured to generate a virtual image.

FIG. **2** illustrates an example environment in which a virtual image device can be implemented.

FIG. **3** is a detailed example of two liquid crystal diffraction gratings that are substantially orthogonally-oriented to each other.

FIG. **4** is a more-detailed example of a virtual image device.

FIG. **5** is another more-detailed example of virtual image device when implemented as a pair of rectangular eyeglasses in accordance with one embodiment.

FIG. **6** illustrates an example method for controlling a virtual image device to generate a virtual image.

FIG. **7** illustrates an example device in which techniques for a virtual image device can be implemented.

DETAILED DESCRIPTION

Overview

It is well know that if a picture is placed in the focal plane of a lens, and an eye looks through the lens from its other focal plane, that the eye will see a virtual image. This arrangement, however, is bulky and unsuitable for integration into a pair of eyeglasses and other slim devices. A wedge light guide is a lens with a focal plane at one end of the light guide so that the arrangement is slim. Consider for example, FIG. **1**, which illustrates an example embodiment **100** of a wedge light guide **102** and a projector **104**. Projector **104** projects light rays **106** and **108** into the thick end of the wedge light guide causing the light rays to reflect back and forth at progressively steeper angles until a "critical angle" is reached, at which point the light rays exit the wedge light guide causing a projected image **110** to emerge from the face of the wedge.

However, a wedge light guide, by itself, is unsuitable to generate virtual images when coupled to a pair of eyeglasses for the following reasons: 1) the focal plane of the wedge light guide is one dimensional making it difficult to project a large virtual image, 2) the focal length of the wedge light guide is too large, and 3) the field-of-view of a virtual image projected by the wedge light guide is too narrow.

This document describes various apparatuses embodying, and techniques for implementing, a virtual image device. This virtual image device includes a projector and a lens configured to generate a virtual image, such as a wedge light guide type of lens. In some embodiments, the lens is a wedge light guide. The virtual image device further includes two diffraction gratings, substantially orthogonally-oriented to each other, that act to increase a field-of-view of the virtual image. The two diffraction gratings can include a horizontal liquid crystal diffraction grating configured to increase a vertical field-of-view of the virtual image and a vertical liquid crystal diffraction grating configured to increase a horizontal field-of-view of the virtual image. The virtual image device may be implemented as a pair of eyeglasses and controlled to generate the virtual image for a wearer of the eyeglasses.

Example Environment

FIG. **2** is an illustration of an example environment **200** in which a virtual image device can be implemented. Environment **200** can be implemented in a virtual image device **202**, which is illustrated, by way of example and not limitation, as a pair of eyeglasses **204**. Eyeglasses **204** can include sunglasses, spectacles, goggles, or any other type of head-mounted display device. While virtual image device **202** will be described as being implemented as a pair of eyeglasses **204**, it is to be noted that virtual image device may also be implemented as any other type of virtual image display device that can generate three-dimensional (3D) and/or multi-view images, such as a television device **206**.

Virtual image device **202** includes processor(s) **208** and computer-readable media **210**, which includes memory media **212** and storage media **214**. Computer-readable media **210** also includes a controller **216**. How controller **216** is implemented and used varies, and is described as part of the methods discussed below.

Virtual image device **202** includes a projector **218** and a lens **220** that can be controlled by controller **216** to generate a virtual image that can be viewed by a wearer of eyeglasses **204**, referred to as "viewer" herein. The frame of a pair of eyeglasses may be slightly curved, which may render regular projectors unsuitable. Therefore, in some embodiments, projector **218** is a holographic projector that can be controlled to adjust to the curvature of a pair of eyeglasses. In some embodiments, lens **220** can be implemented as a wedge light guide. As described herein, the term "wedge light guide" describes a wedge-shaped lens or light guide that permits light input into the wedge light guide to fan out within the wedge light guide via total internal reflection before reaching a critical angle for internal reflection and exiting via another surface of the wedge light guide. The light may exit the wedge light guide at a glancing angle relative to the viewing surface of the wedge light guide to generate a virtual image.

Virtual image device **202** further includes two diffraction gratings **222**, substantially orthogonally-oriented to each other, configured to increase a field-of-view of the virtual image. As described herein, the term "diffraction gratings" includes any type of diffractive optical element. In some embodiments, the diffraction gratings comprise liquid crystal diffraction gratings. Projector **218**, lens **220**, and diffraction gratings **222** may be coupled to lenses of eyeglasses **204** to generate a virtual image of infinitely distant objects directly in front of the viewer's eye to cause a pupil of the viewer's eye to adjust to an infinite or near-infinite focal length to focus on the objects. Projector **218** may be at least partially transparent so that the viewer can see external objects as well as virtual images when looking through the lenses of eyeglasses **204**. In addition, it is to be appreciated that projector **218** may be small enough to fit onto the lenses of eyeglasses **204** without being noticeable to the viewer.

In some embodiments, projector **218** can be implemented as two projectors to generate a virtual image in front of each of the viewer's eyes. When two projectors are used, each projector **218** can project the same virtual image concurrently so that the viewer's right eye and left eye receive the same image at the same time. Alternately, the projectors may project slightly different images concurrently, so that the viewer receives a stereoscopic image (e.g., a three-dimensional image).

In some embodiments, virtual image device **202** may also include a pupil tracker **224** that locates and tracks positions of the pupils of the viewer. Pupil tracker **224** provides these positions to controller **216** to enable the controller to control virtual image device **202** to render the virtual image based on the positions of the pupils of the viewer. For example, controller **216** can control virtual image device **202** to generate a virtual image that concentrates through pupils of a viewer. In some embodiments, pupil tracker **224** is further configured to determine a change in the positions of the pupils. For example, pupil tracker **224** can determine when the pupils move left, right, up, or down. Pupil tracker **224** provides this change in the positions of the pupils to controller **216** to enable controller **216** to control virtual image device **202** to generate the virtual image based on the change in the positions of the pupils.

In some cases, pupil tracker **224** includes an infrared-sensitive camera and a synchronously modulated infra-red LED. Pupil tracker **224** locates the positions of the pupils by taking a picture of the viewer with a flash and identifying "red eye" caused by the flash to locate the positions of the pupils. For example, the positions of the pupils, as indicated by the red eye, can be identified in an otherwise low contrast infra-red image of the viewer's face.

In some cases, virtual image device **202** includes light re-director **226**, which is located adjacent to a viewing surface of lens **220** to diffuse collimated light emitted by lens **220**. This collimated light may exit lens **220** at a glancing angle with respect to the viewing surface. Thus, light re-director **226** can re-direct the emitted light of lens **220** towards the pupils of a viewer and may provide a diffusing function in one dimension. Light re-director **226** can be configured as any suitable structure, such as a turning film of prisms or a light-guide panel having a prismatic textured surface. By varying angles of prisms or prismatic features over a surface of light re-director **226**, light re-director **226** can be configured to have optical power capable of directing the collimated light emitted from the viewing surface of lens **220** towards the pupils of the viewer.

In order to generate a virtual image, light rays from projector **218** are deflected as the light rays exit lens **220** so that the light rays concentrate through each pupil of the viewer. A two-dimensional liquid crystal display (LCD), which modulates light rays in both the vertical and horizontal directions, can be configured to deflect the light rays to concentrate through each pupil of the viewer. For example, a two-dimensional LCD can be controlled to alternate between being opaque and transparent so that it acts like a diffraction grating. Alternately, the LCD can be configured to modulate the phase of light so it acts like a blazed diffraction grating. Conventional LCDs, however, have pixels no smaller than five microns so the deflection angle is only a few degrees. This small deflection angle can cause a small virtual image to be generated. Furthermore, two-dimensional LCDs may use an active matrix of transistors. When the LCDs are opaque, the transistors cause aperture diffraction of external light coming from the outside world. Accordingly, in accordance with various embodiments, virtual image device **202** uses two diffraction gratings **222**, substantially orthogonally-oriented to each other, to deflect light rays leaving lens **220** to cause the light rays to concentrate through the pupils of the viewer.

In an embodiment, the two liquid crystal diffraction gratings **222** can be positioned behind an LCD of virtual image device **202** to scan the illumination of the LCD. Using two liquid crystal diffraction gratings **222** to scan the illumination separate from the LCD enables virtual image device **202** to be equipped with a low resolution LCD because the LCD does not need to scan the image.

FIG. **3** illustrates a detailed example of two diffraction gratings **222** that are substantially orthogonally-oriented to each other. In some embodiments, the two diffraction gratings are passive liquid crystal diffraction gratings that do not require transistors to modulate light rays. By eliminating the need for transistors, the passive liquid crystal diffraction gratings will have substantially less unwanted diffraction of external light. Each of the two liquid crystal diffraction gratings **222** are configured to scan light rays in a single direction (e.g., vertically or horizontally). Scanning light rays in a single direction is known in the art, and is not discussed in detail herein.

Liquid crystal diffraction gratings **222**, in this example, include vertical liquid crystal diffraction grating **302** and horizontal liquid crystal diffraction grating **304**, which are substantially orthogonally-oriented to each other. Vertical liquid crystal diffraction grating **302** includes vertical diffraction gratings to scan the virtual image horizontally (e.g., side to side). Horizontal liquid crystal diffraction grating **304** includes horizontal diffraction gratings to scan the virtual image vertically (e.g., up and down). By aligning vertical liquid crystal diffraction grating **302** orthogonal to horizontal liquid crystal diffraction grating **304**, the virtual image can be separately scanned at a large angle in both the horizontal and vertical directions. The two liquid crystal diffraction gratings, therefore, increase the field-of-view of the virtual image on both a horizontal and a vertical plane to generate a virtual image with a wide field-of-view.

FIG. **4** illustrates a detailed example of virtual image device **202** in accordance with various embodiments. In this example, virtual image device **202** includes a first projector **402** that injects light into a first wedge light guide **404**, a second projector **406** that injects light into a second wedge light guide **408**, a horizontal liquid crystal diffraction grating **410**, and a vertical liquid crystal diffraction grating **412**. In this example, horizontal liquid crystal diffraction grating **410** is between the wedges and vertical liquid crystal diffraction grating **412**. Alternately, the positions of the diffraction gratings can be switched so that vertical liquid crystal diffraction grating **412** is between the wedges and horizontal liquid crystal diffraction grating **410**. Light injected by first projector **402** into first light guide **404** generates a first virtual image **414** that can be viewed by a right eye of the viewer. Light injected by second projector **406** into second wedge light guide **408** generates a second virtual image **416** that can be viewed by a left eye of the viewer.

Horizontal liquid crystal diffraction grating **410** receives first virtual image **414** and second virtual image **416** and increases the vertical field-of-view of the first virtual image and the second virtual image by scanning the virtual images in the vertical direction. Vertical liquid crystal diffraction grating **412** receives first virtual image **414** and second virtual image **416** and increases the horizontal field-of-view of the first virtual image and the second virtual image by scanning the virtual images in the horizontal direction. In some embodiments, first virtual image **414** and second virtual image **416** are the same virtual image so that the right eye and left eye of the viewer see the same virtual image. Alternately, first virtual image **414** and second virtual image **416** may be slightly different virtual images, so that the viewer receives a stereoscopic image.

In some embodiments, virtual image device **202** can be implemented as rectangular eyeglasses with rectangular lenses to further increase the field-of-view of virtual images projected by virtual image device **202**. FIG. **5** illustrates an example of virtual image device **202** when implemented as rectangular eyeglasses **502**. In this example the lenses of rectangular eyeglasses **502** are tilted, relative to a face of a wearer of the eyeglasses, to take advantage of the diagonal from corners **504** to **506**, from corners **508** to **510**, from corners **512** to **514**, and from corners **516** to **518** of rectangular eyeglasses **502** to maximize the field-of-view of virtual images generated by the eyeglasses. In other words, by tilting the glasses, a wider viewing surface is created because the length of the diagonal of a rectangle is longer than the length of either side of the rectangle.

Additionally, by tilting rectangular eyeglasses **502** relative to the wearer's face, a converged area is created below the nose of the wearer of the eyeglasses, which can be used to display virtual images for hand-eye-coordination tasks. For example, corners **512** and **516** create a stereo area where each eye of the wearer can look down to where the wearer's hands typically are located to give an extended stereo area to display virtual images for hand-eye-coordination tasks. The configuration of rectangular eyeglasses **502** also creates "heads up" zones at the upper corners **504**, **508**, **514**, and **518**, which enables display of information that is out of the way of the wearer's primary focus of interest. For example, corners **504** and **508** enable the field-of-view for each eye of the wearer to extend across the nose to create a stereo area where each eye can look across the nose to see what the other eye sees. Corners **514** and **518**, located at the upper outer corners of rectangular eyeglasses **502**, provide an extended heads up display area.

Example Method

FIG. **6** is flow diagram depicting an example method **600** for controlling a virtual image device to generate a virtual image. Block **602** receives data corresponding to a virtual image (e.g., video data corresponding to a movie or to television programming) Block **604** receives positions of pupils of a viewer. For example, controller **216** receives the positions of the pupils of the viewer from pupil tracker **224**.

Block **606** controls a projector to inject light rays into a lens positioned proximate two liquid crystal diffraction gratings, substantially orthogonally-oriented to each other, effective to generate the virtual image with a wide field-of-view based on the positions of the pupils of the viewer. For example, controller **216** controls projector **218** to inject light rays into lens **220** positioned proximate two liquid crystal diffraction gratings **222** effective to generate the virtual image with a wide field-of-view based on the positions of the pupils of the viewer.

Block **608** receives a change in the positions of the pupils of the viewer. Block **610** controls the projector to inject light rays into the lens effective to generate the virtual image with a wide field-of-view based on the change in the positions of the pupils of the viewer. For example, controller **216** controls projector **218** to inject light rays into lens **220** positioned proximate the two liquid crystal diffraction gratings **222** effective to generate the virtual image with a wide field-of-view based on the change in the positions of the pupils of the viewer.

Example Device

FIG. **7** illustrates various components of example device **700** that can be implemented as any type of client, server, and/or display device as described with reference to the previous FIGS. **1-6** to implement apparatuses embodying, and techniques enabling, a virtual image device. In embodiments, device **700** can be implemented as one or a combination of a wired and/or wireless device, a head-mounted display device (e.g., eyeglasses, sunglasses, etc.) as a form of flat panel display, television, television client device (e.g., television set-top box, digital video recorder (DVR), etc.), consumer device, computer device, server device, portable computer device, user device, communication device, video processing and/or rendering device, appliance device, gaming device, electronic device, and/or as another type of device. Device **700** may also be associated with a viewer (e.g., a person or user) and/or an entity that operates the device such that a device describes logical devices that include users, software, firmware, and/or a combination of devices.

Device **700** includes communication devices **702** that enable wired and/or wireless communication of device data **704** (e.g., received data, data that is being received, data scheduled for broadcast, data packets of the data, etc.). The device data **704** or other device content can include configuration settings of the device, media content stored on the device, and/or information associated with a user of the device. Media content stored on device **700** can include any type of audio, video, and/or image data. Device **700** includes one or more data inputs **706** via which any type of data, media content, and/or inputs can be received, such as user-selectable inputs, messages, music, television media content, recorded video content, and any other type of audio, video, and/or image data received from any content and/or data source.

Device **700** also includes communication interfaces **708**, which can be implemented as any one or more of a serial and/or parallel interface, a wireless interface, any type of network interface, a modem, and as any other type of communication interface. The communication interfaces **708** provide a connection and/or communication links between device **700** and a communication network by which other electronic, computing, and communication devices communicate data with device **700**.

Device **700** includes one or more processors **710** (e.g., any of microprocessors, controllers, and the like), which process various computer-executable instructions to control the operation of device **700** and to enable techniques for implementing a virtual image device. Alternatively or in addition, device **700** can be implemented with any one or combination of hardware, firmware, or fixed logic circuitry that is implemented in connection with processing and control circuits, which are generally identified at **712**. Although not shown, device **700** can include a system bus or data transfer system that couples the various components within the device. A system bus can include any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures.

Device **700** also includes computer-readable storage media **714**, such as one or more memory devices that enable persistent and/or non-transitory data storage (i.e., in contrast to mere signal transmission), examples of which include random access memory (RAM), non-volatile memory (e.g., any one or more of a read-only memory (ROM), non-volatile RAM (NVRAM), flash memory, EPROM, EEPROM, etc.), and a disk storage device. A disk storage device may be implemented as any type of magnetic or optical storage device, such as a hard disk drive, a recordable and/or rewriteable compact disc (CD), any type of a digital versatile disc (DVD), and the like. Device **700** can also include a mass storage media device **716**.

Computer-readable storage media **714** provides data storage mechanisms to store the device data **704**, as well as various device applications **718** and any other types of information and/or data related to operational aspects of device **700**. For example, an operating system **720** can be maintained as a computer application with the computer-readable storage media **714** and executed on processors **710**. The device applications **718** may include a device manager, such as any form of a control application, software application, signal-processing and control module, code that is native to a particular device, a hardware abstraction layer for a particular device, and so on.

The device applications **718** also include any system components or modules to implement techniques using or enabling a virtual image device. In this example, the device applications **718** can include controller **216** for controlling a virtual image device.

Conclusion

This document describes various apparatuses embodying, and techniques for implementing, a virtual image device. Although the invention has been described in language specific to structural features and/or methodological acts, it is to be understood that the invention defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed invention.

What is claimed is:

1. A virtual image device comprising: a projector configured to output light rays; a lens configured to receive the light rays from the projector and to generate a virtual image; and two diffraction gratings, positioned proximate the lens, to increase a field-of-view of the virtual image, the two diffraction gratings substantially orthogonally-oriented to each other, a first diffraction grating of the two diffraction gratings configured to increase a vertical field-of-view of the virtual image and a second diffraction grating of the two diffraction gratings configured to increase a horizontal field-of-view of the virtual image.

2. The virtual image device as described in claim **1**, wherein the two diffraction gratings comprise passive liquid crystal diffraction gratings.

3. The virtual image device as described in claim **2**, wherein the virtual image device comprises a pair of eyeglasses, and wherein the projector, the lens, and the two passive liquid crystal diffraction gratings are coupled to the pair of eyeglasses to generate the virtual image for a wearer of the pair of eyeglasses.

4. The virtual image device as described in claim **1**, wherein the first diffraction grating comprises a horizontal diffraction grating, and wherein the second diffraction grating comprises a vertical diffraction grating.

5. A virtual image device as described in claim **1**, wherein the virtual image device comprises a pair of eyeglasses, and wherein lenses of the pair of eyeglasses are rectangular, and tilted relative to a face of the wearer, to maximize the vertical field-of-view and the horizontal field-of-view of the virtual image.

6. The virtual image device as described in claim **1**, wherein the virtual image device comprises a three-dimensional display device or a multi-view display device.

7. The virtual image device as described in claim **1**, further comprising a pupil tracker configured to locate positions of pupils of a viewer, wherein the virtual image device is controlled to generate the virtual image based on the positions of the pupils.

8. The virtual image device as described in claim **7**, further comprising a light re-director to deflect the virtual image based on the positions of the pupils of the viewer.

9. The virtual image device as described in claim **1**, wherein the lens comprises a wedge light guide, the wedge light guide configured to receive the light rays from the projector and to generate the virtual image by projecting the virtual image from a surface of the wedge light guide.

10. The virtual image device as described in claim **1**, wherein the lens is further configured to generate the virtual image for a first eye of a viewer and the virtual image device further comprises:

an additional projector configured to output additional light rays; and

an additional lens configured to receive the additional light rays from the additional projector and to generate an additional virtual image for a second eye of the viewer.

11. The virtual image device as described in claim **1**, wherein the projector is at least partially transparent.

12. The virtual image device as described in claim **1**, wherein the projector comprises a holographic projector.

13. A head-mounted display device comprising:

a pupil tracker configured to locate a position of a first pupil and a position of a second pupil of a wearer of the head-mounted display device;

a first projector configured to inject light rays into a first wedge light guide effective to generate a first virtual image based on the position of the first pupil;

a second projector configured to inject light rays corresponding to the virtual image into a second wedge light guide effective to generate a second virtual image based on the position of the second pupil;

two liquid crystal diffraction gratings, substantially orthogonally-oriented to each other, comprising:

a horizontal liquid crystal diffraction grating configured to increase a vertical field-of-view of the first virtual image and the second virtual image; and

a vertical liquid crystal diffraction grating configured to increase a horizontal field-of-view of the first virtual image and the second virtual image.

14. The head-mounted display device as described in claim **13**, wherein the head-mounted display device is a pair of eyeglasses.

15. The head-mounted display device as described in claim **13**, wherein the head-mounted display device comprises a pair of eyeglasses, with rectangular lenses that are tilted relative to a face of the wearer, to further increase the vertical field-of-view and the horizontal field-of-view of the virtual image.

16. The head-mounted display device as described in claim **13**, further comprising a turning film configured to direct the first virtual image to the first pupil and to direct the second virtual image to the second pupil.

17. A virtual image device comprising:

a pupil tracker configured to locate positions of pupils of a viewer;

a projector configured to output light rays;

a lens configured to receive the light rays from the projector and to generate a virtual image based on the position of the pupils of the viewer; and

two diffraction gratings, positioned proximate the lens, to increase a field-of-view of the virtual image, the two diffraction gratings substantially orthogonally-oriented to each other.

18. The virtual image device as described in claim **17**, further comprising a light re-director to deflect the virtual image based on the positions of the pupils of the viewer.

19. The virtual image device as described in claim **17**, wherein the lens comprises a wedge light guide, the wedge light guide configured to receive the light rays from the projector and to generate the virtual image by projecting the virtual image from a surface of the wedge light guide.

20. The virtual image device as described in claim **17**, wherein the virtual image device comprises a head-mounted display device.

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